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Information Model and Its Element for Displaying Information on Technical Condition of Objects of Integrated Information System

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ABSTRACT

The suggested information elements for the system of information display of the technical condition of the integrated information system meet the essential requirements of the information presentation. They correlate with the real object simply and very accurately. The suggested model of information display of the technical condition of the objects of integrated information system improves the efficiency of the operator of technical diagnostics in evaluating the information about the technical condition of the integrated information system.

Keywords: *evaluation of technical condition, integrated information system, information model, technical diagnostics.*

I. DEFINITION OF PROBLEM

There is a need for creating a public integrated information system (IIS) of management of moving objects (communication, navigation, surveillance). This need is caused by fragmentation of authority and is connected with duplication in the use of existing information systems, insufficient bandwidth channels and networks communication, lack of appropriate equipment on moving objects and obsolete infrastructure of information provision.

The analysis of the functioning of the integrated information system [1] suggests that its major drawback is the lack of technical diagnostics system, which reduces its effectiveness. Traditional methods of technical diagnostics (hardware and functional control) will be ineffective because a large number of objects of diagnostics, difficulty and impropriety of protocols of different levels prevent effective formalization of the technical diagnostics of the IIS.

Evaluation of the technical state of the elements of the IIS is performed on the basis of the decision that diagnostic parameters comply with diagnostic standards. Evaluating the condition of the system with a large number of objects involves collecting and summarizing large data sets in the minimum possible time.

Addressing issues related to the improvement of information decision making support by a decision maker (DM) and operators of technical diagnosis (OTD) is not possible without using new approaches to obtaining, processing and presentation of information. Factors enabling the improvement of information support include [2]: relevance of the information model to modern conditions; relevance of the information model and its fragments to the tasks performed by DMs and operators; information model structure (the number of levels of detalization and degree of grouping, detalization of data on different states, etc.); compliance of the information model with ergonomic design principles; compliance of the information model with peculiarities of intellectual activity of DMs and operators; relevance of the displayed information to the tasks performed by the DMs and operators; improvement of communication between the DMs and operators and automation devices; increasing the level of automatization of DMs and operators's activities; relevance of the information model to specific technical diagnostics tasks; improvement of professional selection process of DMs and operators, their training and their professional knowledge and skills support.

To achieve this the development of information elements for the system of the display of the information on the technical condition of the IIS is required.

The aim of this work is to develop information elements as mnemonic symbols for the system of the display of the information about the technical condition of IIS and information models, application of which will help to reduce the time required for making decisions on resumption of work of the IIS. That, in turn, will fully realize the potential of the IIS and increase its effectiveness.

The Information Model (IM) is a syntactic or semantic description presented in the form of graphic images that reflects the properties, characteristics and relationships of the object, process or phenomenon. With the help of the information model it is necessary to describe the technical condition of the IIS for every time point, which will allow a DM to make an optimal decision to restore the lost functionality of the IIS elements and the system in general as soon as possible. Thus, the choice of the information model and means of its elements representation is very important.

At present, the most widely used types of these information models [2] are: verbal, tabular, hierarchical, graphical, mathematical, network, and others.

Analysis of the types of IMs suggests that in order to create an IM for assessing the technical condition of the IIS, tabular and graphical IM can be used. The number of items of the IIS, information on which should be submitted to the DM, is quite large. So, it is logical to choose a graphic IM in the form of graphic mnemoscheme. Such an IM can be better seen and perceived [3]. Thus, the IM of the technical condition of the IIS as a graphical mnemoscheme is developed. It should be considered that the basic requirements when selecting the form of the presentation of objects on mnemoschemes is the simplicity and high accuracy of mnemosign relation to the real object. This requires pre-classification of the items of the IIS and choosing some form of sign of the information element for each class. The IIS is composed of the following elements: control points (CP), information sources (IS), checkpoints (C) and complex automation facilities (CAF).

Let us look at the presentation of the states and operating modes of the information sources which are part of the IIS. It is conditioned by a large variety and functionality of information sources. Let us outline their preliminary classification. The sources of information for the IIS are radars:

- Primary radars that operate on the principle of electromagnetic irradiation of the target and the reception of the reflected echo signal (Fig. 1a);
- Secondary radars that operate on the basis of emitting a request signal on centimeter wavelengths and reception of the response signal from the respondent, located on board of an object (Fig. 1 B).

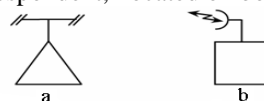


Figure 1. Mnemosigns to display radar autonomous class:
a - primary radars; b - secondary radars

To indicate the radars connected to CAF on the mnemonic scheme the characters represented in Fig. 2. are proposed



Figure 2. Mnemosigns for displaying radar class, which are connected to automation facilities complex: a - primary radars; b - secondary radars

Primary radars are divided according to the range of wavelengths they work on into centimeter, decimeter and meter. Radio altimeters are considered a separate type of radars (Fig. 3).

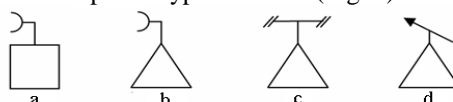


Figure 3. Mnemosigns for displaying primary tow-dimensional radars: a - a primary radar of centimeter range; b - a primary radar of decimeter range; c - a primary radar of metric range; d – altimeter

According to the number of coordinates that are measured, primary radars can be two-dimensional (azimuth and range of an air object (AO) relative to the location of radars are measured) (see. Fig. 3) and three-dimensional (azimuth, elevation angle and range of AO are measured) (Fig. 4).

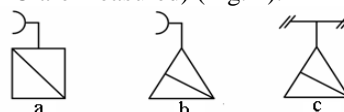


Figure 4. Mnemosigns for displaying three-dimensional primary radars: a - a primary three-dimensional centimeter range radar; b - a primary three-dimensional decimeter range radar; c - a primary three-dimensional meter range radar

Radars as an information source in the IIS can be in the following states: the radar is in working order - operable; radar malfunction - operable; radar malfunction - disabled.

For their coding use of colour is proposed [4]. When choosing colours for displaying signs for mnemoschemes, it is advisable not to overuse the colours which tire the operator's eyes quickly, such as red and purple. Therefore, to display the states of radars such colours are recommended:

- In working order - operable - green;
- Radar malfunction - operable - beige;
- Radar malfunction - disabled - red.

The use of red is not contrary to the recommendations of the engineering psychology. It denotes malfunction and signals the necessity to restore the operable state of the radar. For the background of the mnemoschemes it is recommended to use a rectangle, in which the symbol of an information source is placed with the appropriate colour: green - radar enabled, yellow - radar switched off (Fig. 5).

For characters marking the control points on the mnemoscheme, it is proposed to use a circle, for checkpoints – a square, and for CAF – a diamond.

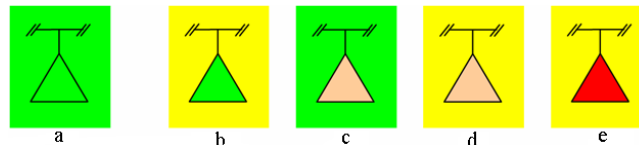


Figure 5. Mnemosigns for displaying radar possible states: a - the radar is working - operable - enabled; b - radar is working - operable - disabled; c - radar malfunction - operable - enabled; d - radar malfunction - operable - disabled; e - radar malfunction - unable to work. According to hierarchy, all these elements of the IIS belong to low, medium or high rank (Fig. 6-8)

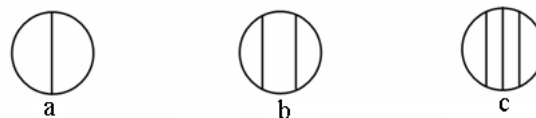


Fig. 6. Mnemosigns for displaying control points: a – CP of low rank; b - CP of medium rank, c - CP of high rank

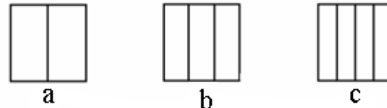


Fig. 7. Mnemosigns for displaying checkpoints: a – C of low rank; b - C of medium rank, c - C of high rank

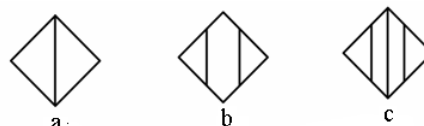


Fig. 8. Mnemosigns for displaying CAF: a – CAF of low rank; b - CAF of medium rank, c - CAF of high rank

In the same way as for radars it is proposed to use colour to display the technical condition of CP, C and CAF.

While developing the IM, the division of the working field of the monitor according to functional groups of mnemosigns was conducted taking into account:

- The spatial position of real objects of the IIS;
- Importance of the contribution of the objects of a particular group to performing the task;
- Standard recommendations on making more important elements more prominent in size.

Consideration of the set of sometimes conflicting requirements led to obtaining such average geometrical dimensions of signs and their elements:

- a typical element of the rectangle;
- an isosceles triangle;
- signs of objects with:

a) external contour;

b) internal contour - length 25 mm, height 15 mm;

- radar antenna: length 20 mm, height 10 mm, minimum element size - 5 mm

The size of the simplest figures reflecting the state of various real objects can deviate in either direction to improve the overall structure of the mnemonic scheme. As noted earlier, the screen display provides the status of the integrated model of distant objects. It reflects its general condition: working order, operability, enabled - disabled state. A detailed model can be displayed on an additional panel screen.

II. CALCULATING THE AMOUNT OF TIME NEEDED FOR A PERSON TO MAKE A DECISION CONCERNING THE TECHNICAL STATE OF THE ELEMENTS OF THE INTEGRATED INFORMATION SYSTEM

Assuming, there is a set of elements of the IIS I . It includes information sources (navigation tools, observations), means of communication and information centers of the IIS. The person assessing the technical condition of the elements I and the integrated information system as a whole is called the operator of technical diagnostics (OTD) of the set of elements I .

Activity of OTD is performed in a complex dynamic environment. In order to design effective information support of their activities preliminary evaluation is necessary. Simulation models are used to analyze the information support of the activity of OTD and building situations close to the real objects of modeling. Simulation models are characterised by possibility of taking into account many factors and relations which are difficult to formalize. In the absence of the real object of the modeling, these models can serve as its counterparts when checking the characteristics of the models.

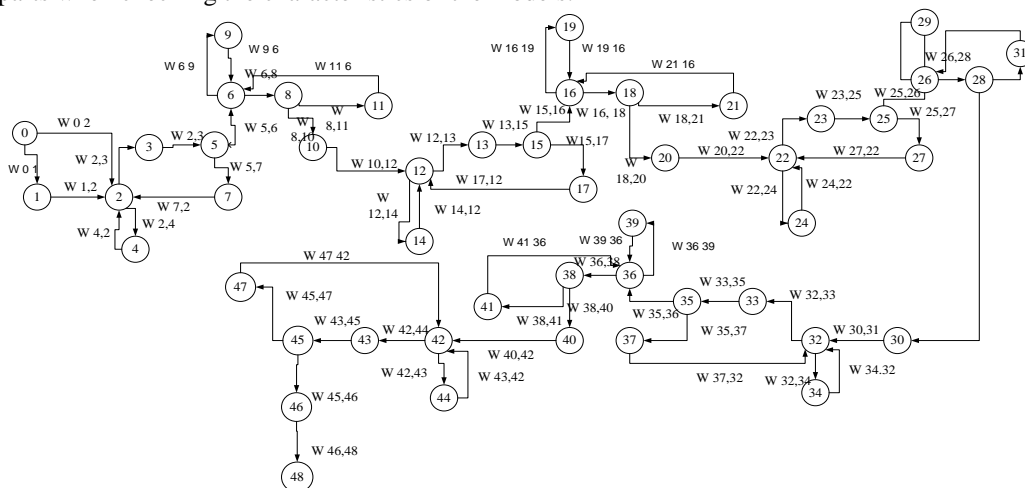


Figure 9. The model of the activities of OTD while clarifying information on the technical condition of the set of elements I

Graphic-analytical method as a kind of simulation modeling techniques involves "manual" calculation of possible mathematical expectations, special nomograms and the simplest analytical calculations [5]. Its counterpart in the implementation of electronic computers is the method of average value time. The application of this method provides analytical calculation of the number of possible actions and the likelihood of transition after their execution to other actions performed by OTD with a known minimum and maximum time spent. Taking into account the probability of performing an action, mathematical expectation of the number of performed actions and transitions between them is determined, as well as the probability of performing an action per time unit. In order to study the expected progress and results of the activities of OTD a model of the activities of OTD is required. This model is a physical, mental or combined analog of the activities reflecting the patterns of performed tasks, basic physical and information links between them.

The existing information model of the OTD examining their activity to obtain information on the technical condition of the set of elements I can be represented by a graph shown in (Fig. 9). On the graph the points correspond to events, such as "OTD gets to know the technical condition of IS." Edges correspond to probability of transition from one event to another and time required for this transition. Let us define the content of the points of the graph, the content and sequence of transitions between points (Table. 1, 2).

Table 1. Event of the process of acquiring information

Event	The content of the event
0	The command to issue information on the technical condition of IS is received
1	OTD is not in the workplace, comes to the automated workplace
2,12,22,32	OTD dials the number of the correspondent IS
3,13,23,33	OTD gets through to the correspondent IS
4,14,24,34	OTD does not get through to the correspondent IS
5,15,25,35	OTD learns about the technical condition of the correspondent IS
6,16,26,36	OTD comprehends the information
7,17,27,37	The connection is cut or the OTD fails to comprehend the information
8,18,28,38	OTD enters data on the technical condition of elements I
9,19,29,39	The delay in the input of data on the technical condition

10,20,30,40	OTD has entered all the data on the technical condition correctly
11,21,31,41	OTD has entered the data on the technical condition incorrectly
42	OTD calls the chief and reports
43	OTD gets through to the chief
44	OTD doesn't get through to the chief
45	OTD reports to the chief about the technical condition of the IS
47	The connection is cut or the chief fails to comprehend the information
46	The chief comprehends the information, the report is admitted
48	The chief takes notes

The model of the activities of OTD is formally given as [6]:

$$P = |p_{ij}|, \quad (1)$$

$$T = |t_{ij}|, \quad (2)$$

where P – matrix of probabilities of transition between events i and j ;

T – matrix of the time spent on work during the transition from event i to event j ;

p_{ij} – probability of transition from event i to event j ;

t_{ij} – the time spent on the transition from event i to event j ;

$i=j=N-i$ correspond to the number of possible states of O(TD).

On Fig.. 9 values p_{ij} and t_{ij} are given as w_{ij} , де $w_{ij} = (p_{ij}, t_{ij})$.

In the simulation modelling process of obtaining information on the technical condition of the set of elements I by OTD, an assumption is made that the process of perceiving information actually comes down to the comprehension of the information and input of the data on the technical condition.

The distribution of random values of time needed for performing tasks when OTD is working with the simulation model is truncated, unimodal and asymmetric [7].

Preserving sufficient accuracy, it is possible to use a special case of Beta distribution, probability density of which is equal:

$$f(\tau) = \begin{cases} 0, & \text{if } ((\tau \leq t_1) \wedge (\tau \geq t_2)), \\ \frac{12}{(t_2 - t_1)^4} (\tau - t_1)(t_2 - \tau)^2 C, & \text{otherwise} \end{cases} \quad (3)$$

In this case the mathematical expectation of time needed for performing tasks by OTD (\bar{t}_p) and dispersion (D_p) are equal correspondently [5]:

$$\bar{t}_p = \frac{3t_1 + 2t_2}{5}, \quad (4)$$

$$D_p = 0.04 (t_2 - t_1). \quad (5)$$

Therefore, to assess the distribution parameters it is enough have information on the minimum (t_1) and maximum (t_2) time spent.

Table 2. The content of state transisions

Transitions	Actions of OTD during transitions from one state to another
w_{01}	OTD comes to the automated workplace
$w_{02}, w_{12}, w_{1012}, w_{2022}, w_{3032}, w_{4042}$	OTD dials the IS
$w_{23}, w_{1213}, w_{2223}, w_{3233}, w_{4243}$	OTD gets through
$w_{35}, w_{1315}, w_{2325}, w_{3335}, w_{4345}$	Information is received
$w_{24}, w_{1214}, w_{2224}, w_{3234}, w_{4244}$	OTD doesn't get through
$w_{42}, w_{72}, w_{96}, w_{116}, w_{1412}, w_{1916}, w_{2116}, w_{2422}, w_{2722}, w_{2926}, w_{3126}, w_{3432}, w_{3732}$	Repeated call

$W_{39\ 36}, W_{41\ 36}, W_{44\ 42}, W_{46\ 42}$	
$W_{5\ 7}, W_{15\ 17}, W_{25\ 27}, W_{35\ 37}, W_{45\ 47}$	The connection is cut or the OTD fails to comprehend the information
$W_{5\ 6}, W_{15\ 16}, W_{25\ 26}, W_{35\ 36}, W_{45\ 46}$	Comprehension of the information
$W_{6\ 8}, W_{16\ 18}, W_{26\ 28}, W_{36\ 38}$	Input of data on the technical condition
$W_{6\ 9}, W_{16\ 19}, W_{26\ 29}, W_{36\ 39}$	The delay in the input of the data
$W_{8\ 11}, W_{18\ 21}, W_{28\ 31}, W_{38\ 41}, W_{8\ 10}, W_{18\ 20}, W_{28\ 30}, W_{38\ 40}$	Validation of data entry
$W_{46\ 48}$	Search for the documents for entering records

For the study of the process of obtaining information, the operation activities of OTD related to the analysis of IM are defined (Fig. 9). The parameters that were evaluated in the course of different actions performed by OTD were: the time spent performing activities, likelihood of completion of these activities and the probability of transition to the next step, the mathematical expectation of the time spent performing the activities on clarifying the state of the set of elements I .

Obtained results of the mathematical expectation of the performance of the activities on the information evaluation using the simulation model are presented in Fig.10, where:

- 1 – use of telephone communication (49%);
- 2 – data processing (8%);
- 3 – entering data on the technical condition (43%).

The obtained results lead to the conclusion that for obtaining and comprehension of the information on the technical state 130 p. is spent

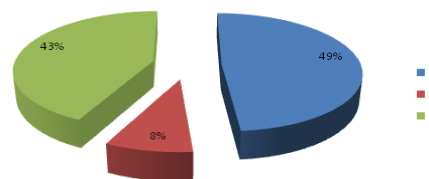


Figure 10. Average time spent by OTD on the analysis of the technical state of the set of the elements I
The implementation of the proposed changes to the system of information support the model of OTD activities is similar to the traditional (Fig. 9). Proposed improvements of the IM of control of the state of the set of elements I will change the model of the activity of OTD (Fig. 11).

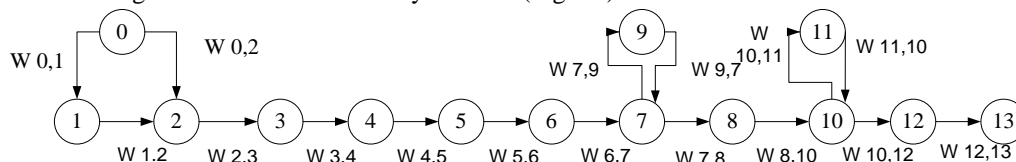


Figure 11. The improved model of the activities of OTD in processing the information on the technical condition of the set of elements I

Let us define the content of the points of the graph, the content and sequence of transitions between points
Obtained results of the mathematical expectation of the performance of the activities on the information evaluation in the IM OTD are presented in Fig.12, where:

- 1 – obtaining information (27%);
- 2 – data processing (38%);
- 3 – reporting on the technical state of the IS to the chief (35%).

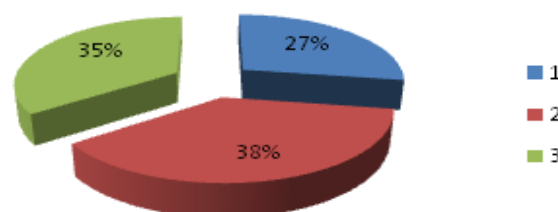


Figure 12. Average time spent by OTD while clarifying the information on the technical condition of the set of elements I

In order to get preliminary quality evaluation, experimental research of both simulation models was conducted [8]. The parameters that were evaluated in the course of different activities performed by OTD were: the time of tasks completion, the likelihood of their completion and the probability of transition to the next activity after the previous one. The findings indicate improvement of OTD's efficiency in clarifying information on the technical condition after using the developed IM. 20 seconds is spent on the acquisition and comprehension of the information about the technical condition of the set of elements *I* performed with the developed IM. Charts comparing time needed according to the existing and proposed information models are shown in Fig. 13.

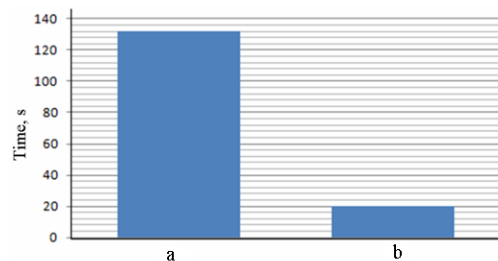


Figure 13. Time spent by OTD using the: a - the existing information model; b - the proposed information model

The improvement of the IM, its adaptation to the capabilities of humans to perceive information, consideration of ergonomic qualities and automation of some processes significantly reduced the time spent on almost all stages of the activities of OTD.

III. CONCLUSION

The information elements for the system of displaying information on the technical condition of the IIS, which simply and accurately correlate to the real object are defined. It was established that it takes the person who makes decisions more than 2 minutes to obtain and comprehend the information on the technical condition of the IIS using the existing information model of evaluating the technical condition of the IIS, while the time spent increases with increase in the number of system components. In the IIS with many elements the overall time of the evaluation of technical condition can reach values that commensurate with the time between failures of individual objects.

The developed information model reduces the time for obtaining and comprehension of the information on the condition of a typical component of the system by more than 1 minute. The proposed model is more adapted to the potential of human perception, it is more ergonomic and automates the evaluation of technical condition.

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